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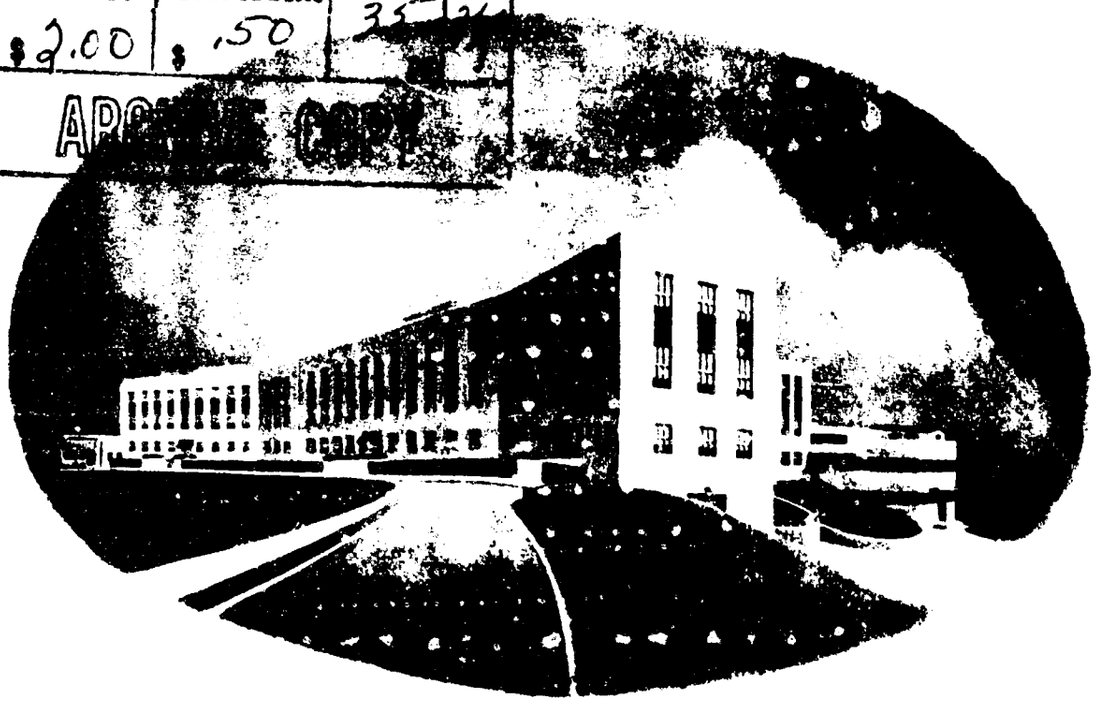

AN EVALUATION OF THE FOAMED NEOPRENE "DIVER'S WET SUIT" AS A SURVIVAL GARMENT FOR HELICOPTER AIRCREWS

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ABSTRACT

AN EVALUATION OF THE FOAMED NEOPRENE "DIVER'S WET SUIT" AS A SURVIVAL GARMENT FOR HELICOPTER AIRCREWS

The type of flights performed by helicopters require particular garments for their aircrews as follows: (1) Water entry by aircrew is by way of water collision so that there is a high probability of damage to the survival garment; (2) The short flight radius of the helicopter ensures that the time-distance from a potential rescuer should be relatively short, so that rescue should be expected in less than 4 hours; (3) The suit must be wearable without an air ventilated suit for cooling and still be usable in high cockpit temperatures up to 90°F; and, (4) The low altitude of flight allows no time to don or zipper up a survival garment so that there should be no significant penalty for entering the water with the garment partially unzipped.

Laboratory experiments using a variety of anti-exposure assemblies demonstrated that the 3/16" foamed neoprene wet suit, mittens, hood, and insulated rubber "thermal" boots provided the most comfortable and efficient configuration. Tolerance times were established for such clothing in 40°, 50°, and 60°F. water.

INTRODUCTION

The problems associated with protecting a downed pilot at sea have been of great concern to the Navy and to the Military Establishment at large. The development of a satisfactory anti-exposure suit has long been a difficult and important problem in the overall concept of survival.[1,2,3,4] Unfortunately, there is no panacea in suit configuration for the aircrew in situations in which extremes of both air and water temperatures vary over wide ranges.[5,6] Traditional approaches to the solution of this problem have been attempts to provide the individual with a watertight envelope beneath which is worn an insulative garment of a weight and volume consistent with the allowable bulk and with insulative values which would not produce heat stress. The difficulties encountered in attempting a watertight suit which would allow extension of the arms and neck through the outer shell and yet provide simple entry to the suit are obvious. Should ditching be necessary, the probability of leakage into the suit around the neck and arms as well as the cold and immersion diuresis rapidly compromise the efficiency of any dry suit insulation.[7] In consideration of these problems, it seemed proper to investigate alternative methods of providing anti-exposure protection during water immersion.[8]

In the fall of 1963, the Bureau of Naval Weapons assigned the Naval Medical Research Institute the task of studying the thermal problems of Naval Aviators assigned to helicopter operations while wearing anti-exposure clothing. Shortly thereafter, the Bureau of Naval Weapons[9] approved the skin diver's unicellular foamed wet suit as an interim anti-exposure garment for helicopter crews pending installation of ventilation blowers in all operational rotary wing aircraft or development of a new type exposure suit. The interim approval of the wet suit necessitated an investigation to delineate the insulative qualities of the unicellular foamed wet suit in various combinations, and to determine its effectiveness as compared to the Navy MK5A anti-exposure suit. In the 61 experiments discussed in this report, the tolerance times and body temperatures of volunteer subjects were determined when they were immersed in 40°, 50°, and 60°F water while clothed in different foamed neoprene anti-exposure suit assemblies and the MK5A anti-exposure garment.

METHODS

Experiments were conducted with personnel dressed in various suit configurations and immersed in water of 40°, 50°, and 60°F temperatures. The basic clothing worn in these experiments consisted of light-weight nylon swim

trunks, wool socks, and a 3/16" unicellular foamed neoprene (UNF) wet suit which included three-fingered gloves and hood. The shoes tested were: (1) Navy thermal boots designed to be worn with MK4 anti-exposure suit; (2) Navy leather flight boots; and, (3) Navy leather flight boots worn over wet suit booties.

In addition, at 40°F, immersion studies were made with subjects dressed in the MK5A anti-exposure suit, consisting of the insulated inner liner, rubberized outer garment, hood, leather gloves, and Navy thermal boots designed to be worn with the MK4 anti-exposure suit.

Body temperature measurements were recorded by means of a thermistor rectal probe (inserted approximately 6-8 cm) and 16 skin temperature sensors distributed over all areas of the body with particular emphasis on the extremities. Skin sensors were located one each on the great toes (2), little toes (2), heels (2), inner thighs (2), calves (2), index fingers (2), upper back (1), lower back (1), right palm (1), and the head (1). Readout was made from two telethermometers.* Electrocardiograms were taken from a forehead-rectal lead. All experiments were conducted at the Naval Medical Research Institute in a circular pool, ten feet in diameter and ten feet deep. The water temperature was thermostatically regulated within $\pm$ 0.5 C

* Yellow Springs Instrument Co., Yellow Springs, Ohio

of the test temperature with the water continuously recirculated and filtered. The water in the tank flowed past the subject at 1/6th of a mile per hour. Air temperature above the pool averaged 65^{o} - 72^{o}F. Subjects wore a Navy MK2 inflatable vest life preserver and were weighted as necessary to insure immersion to the neck level.

Twenty-six Naval personnel, both officer and enlisted, stationed at the Naval Medical Research Institute, were volunteer subjects. These men, representing a cross-section of the on-board personnel, had a mean age of 28.5 years (20-38), a mean height of 176 cm (170-185), a mean weight of 75.7 kgm (63.2-101.5), and a mean total body surface area of 1.91 m^2 (1.71-2.22). Each subject was notified 24 hours before his participation as test subject and instructed to: (1) abstain from alcoholic beverages for 12 hours before the experiment; (2) obtain a normal night's sleep; and, (3) eat a well-balanced breakfast prior to reporting to the laboratory. Upon arrival, each subject donned light-weight nylon swim trunks and had a nude weight and height measurement and resting oxygen consumption determinations made. The subject was then instrumented and dressed in the appropriate clothing configuration. A third resting oxygen consumption determination was then made as the normal value against which the experimental results were to be compared. Pre-immersion temperatures and EKG were recorded. Through the

immersion period, all temperatures were monitored and recorded every twenty minutes. Soon after entering the water, subjects were advised to form their hands into fists within the three-fingered wet suit gloves in order to minimize finger heat loss. Respiratory gas samples were collected every 15 minutes during the first hour and every 30 minutes thereafter. Subjective comments were recorded. The following pre-determined criteria were set as a limit to the immersion period: (1) a fall in rectal temperature to 95°F, (2) a fall in toe or finger temperatures to 45°F, (3) any abnormality in a subject's electrocardiogram, (4) prolonged, severe muscle cramps and (5) the request of a subject to terminate the experiment. Upon completion of the immersion period, subjects were undressed, warmed in a shower until comfortable, and then weighed. All subjects then returned to their normal duties.

The various configurations tested in these studies are as follows:

CONFIGURATION:

A. 3/16" wet suit and thermal boots in 40°, 50°, and 60°F water.

B. 3/16" wet suit, wet suit booties, and leather flight boots in 40°, 50°, and 60°F water.

C. 3/16" wet suit and leather flight boots in 40°F water. (Subjects entered the water prior to donning the wet suit, gloves, and hood and with the neck and sleeve zippers partially open).

D. MK5A, cotton underclothes, MK5A insulative undergarment and anti-exposure suit, with thermal boots in 40°F water. (Boot tops were sealed with tape to inhibit water flow into the boots and around the feet. Subjects exercised caution upon entering the water and throughout the experiments to keep the neckline of the MK5A above water in an effort in minimize leakage into the suits).

E. 3/16" wet suit with electrically heated boots and gloves in 40°F water.

F. 1" wet suit in 40°F water (4 ¼" neoprene foamed (UNF) coveralls, booties, and mitts, worn one over the other).

G. Nylon swim trunks (nude) in 60°F water.

H. Nylon swim trunks (nude) in 50°F water.

Total body heat loss determinations were made for configurations A, D, E, F, G, and H. The rate of total body heat loss was determined by the use of Beckman's formula which is based on the assumption that the skin temperature reflects the temperature of a tissue of 1 cm thickness. The mass of the tissue which is represented by each surface skin temperature sensor is equal to the area of the part in cm^2 times a thickness of 1 cm. The core temperature then represents the difference between the tissue mass of the body minus the 1 cm thick external shell. Total tissue heat loss is added to the heat generated as measured by oxygen consumption to obtain the rate of total body heat loss.

RESULTS:

The mean duration times for the various configurations are outlined in Table I.

TABLE I. EXPERIMENTAL CONDITIONS AND DURATION TIMES FOR WATER IMMERSION STUDIES

CONFIGURATION	NUMBER OF EXPERIMENTS			MEAN TIME (HOURS)		
	40°F	50°F	60°F	40°F	50°F	60°F
A. 3/16" Wet Suit* Thermal Boots	10	10	4	2.5	4.2	6
B. 3/16" Wet Suit** Flight Boots	9	8	3	2.5	3.3	6
C. 3/16" Wet Suit* Flight Boots	3	0	0	1.3	--	--
D. MK5A Anti-Exposure Suit, Thermal Boots	5	0	0	1.4	--	--
E. 3/16" Wet Suit Electrically heated Boots & Gloves	5	0	0	2.7	--	--
F. 1" Wet Suit (4 ½" UNF coveralls, booties, & mitts)	5	0	0	4.5	--	--
G. Nude	0	0	5	--	--	1.8
H. Nude	0	5	0	--	0.98	--

**Booties worn
* Booties not worn

Configuration A (3/16" wet suit and thermal boots) was tested and compared in 40°, 50°, and 60°F water, Figure 1.

CONFIGURATION A at 40°F: (Wet suit and thermal boots). Ten subjects demonstrated an average tolerance time of two hours and thirty minutes (range 2 - 3 hours), Table I. Mean rectal temperature loss by the end of 2 hours was recorded at 1.9°F with the rate of loss for the next hour of 0.3°F. The mean skin temperature of the back (MLB) stabilized at about 74°F after 40 minutes. The temperature of the hands and feet decreased rapidly within the first 20 minutes and by the end of 2 hours, finger temperature (LIF) was 52°F and great toe temperature (LGT) was 50°F. The mean rate of total body heat loss was calculated to be 171.6 kcal/m^2/hr, approximately 3.2 times the pre-immersion value for these ten subjects, Table II.

TABLE II. MEAN TOTAL BODY HEAT LOSS* kcal/m^2/hr

60°F		50°F		40°F	
Air	Water	Air	Water	Air	Water
53.8	95.51	58.7	136.04	52.7	171.61

*Wearing 3/16" Unicellular Foamed Wet Suit and Thermal Boots

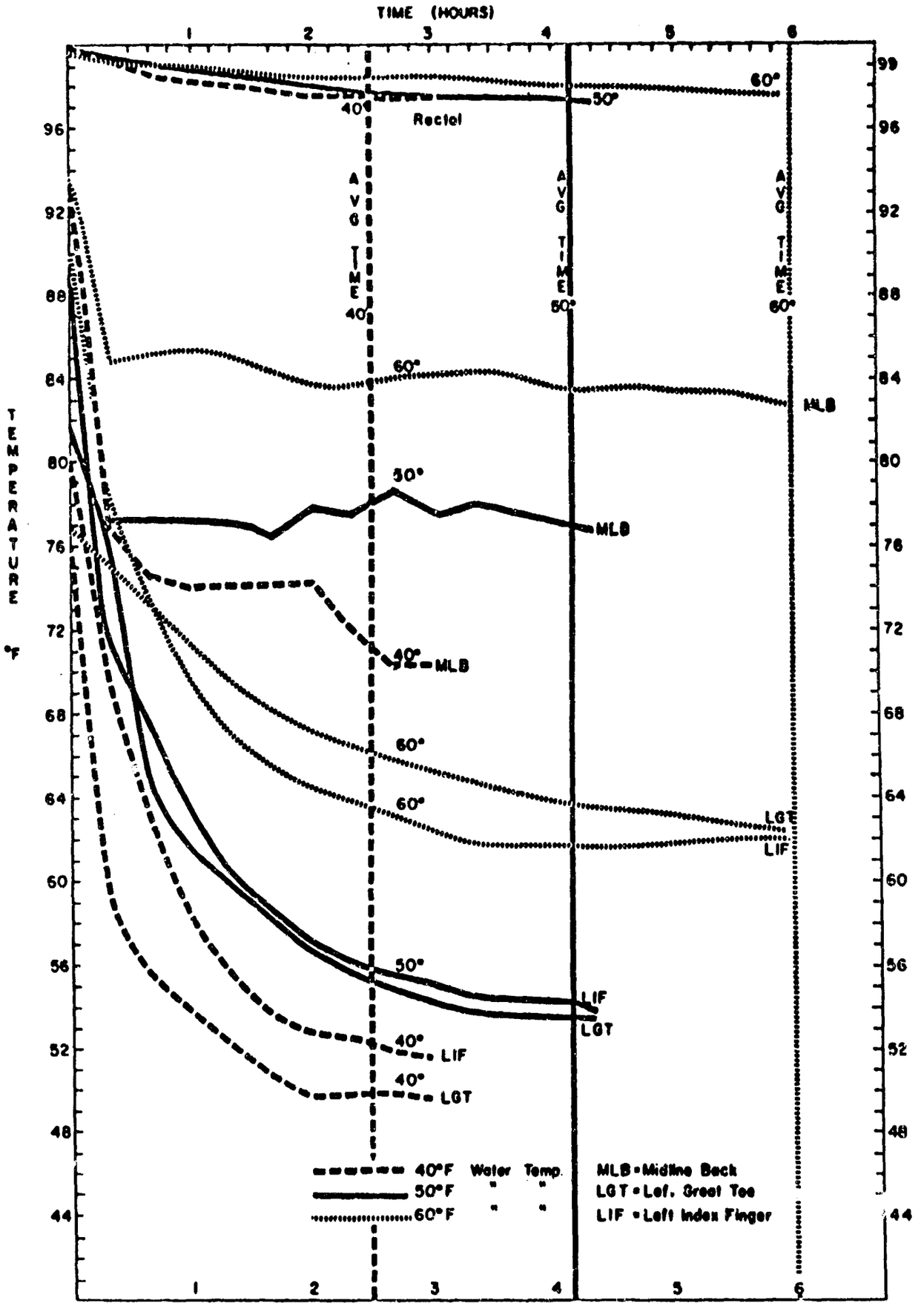

Fig. 1 Comparison of Body Temperatures In 40°, 50°, 60°F Water Wearing 3/16" Unicellular Foamed Wet Suit And Thermal Boots

CONFIGURATION A at 50°F: Ten experiments were conducted in this series with an average tolerance time of 4 hours (range 2.5 - 5 hours). The mean rectal temperature decrease within 2 hours was 1.3°F with 0.2°F decrease per hour thereafter. The mean skin temperature of the back stabilized at 76°F after 20 minutes of immersion. The mean temperatures of the fingers and toes after the rapid decrease of the first 20 minutes continued to fall more slowly registering 55.2 and 53.5°F respectively by the end of the third hour. The mean rate of total body heat loss was 136 kcal/m^2/hr, approximately 2.3 times that of the pre-immersion value.

CONFIGURATION A at 60°F: The four experiments in this series were terminated by the investigator at the end of six hours because skin temperatures stabilized at the end of the fourth hour and rectal temperatures were decreasing not more than 0.1°F per hour. The lowest mean temperatures recorded were those of the fingers and toes at 62°F. The mean rate of total body heat loss during immersion was 95.5 kcal/m^2/hr, or 1.9 times the pre-immersion determination made while seated at rest. Similar measurements were made with subjects wearing configuration B (3/16" wet suit, wet suit booties, flight boots) in 40°, 50°, and 60°F water.

CONFIGURATION B at 40°F: (Wet Suit, wet suit booties, flight boots). The average tolerance time for the nine subjects in this series was the same as for Configuration A. The mean rectal temperature loss by the end of two hours was 1.2°F with an additional 0.5°F loss during the third hour. Mean back and toe temperatures resembled those in Configuration A., although falling a few degrees lower in all cases.

CONFIGURATION B at 50°F: The eight subjects in these experiments averaged 3 hours and 17 minutes with a variation of 1 hour and 40 minutes to 5 hours. The temperatures recorded were essentially the same as for the Configuration A series at this temperature.

CONFIGURATION B at 60°F: The results of this series were essentially the same as those found for Configuration A at 60°F.

CONFIGURATION C at 40°F: (Wet suit, leather flight boots). The three subjects in this series of experiments entered the water prior to donning the wet suit mittens and hood which they were able to don in approximately three minutes. All three experiments were terminated because the subjects had severe pain in the feet, within 80 minutes. The mean rectal temperature decrease for the 80 minute period was 0.6°F, similar to the decrease seen in Configurations A and B, (Fig.2).

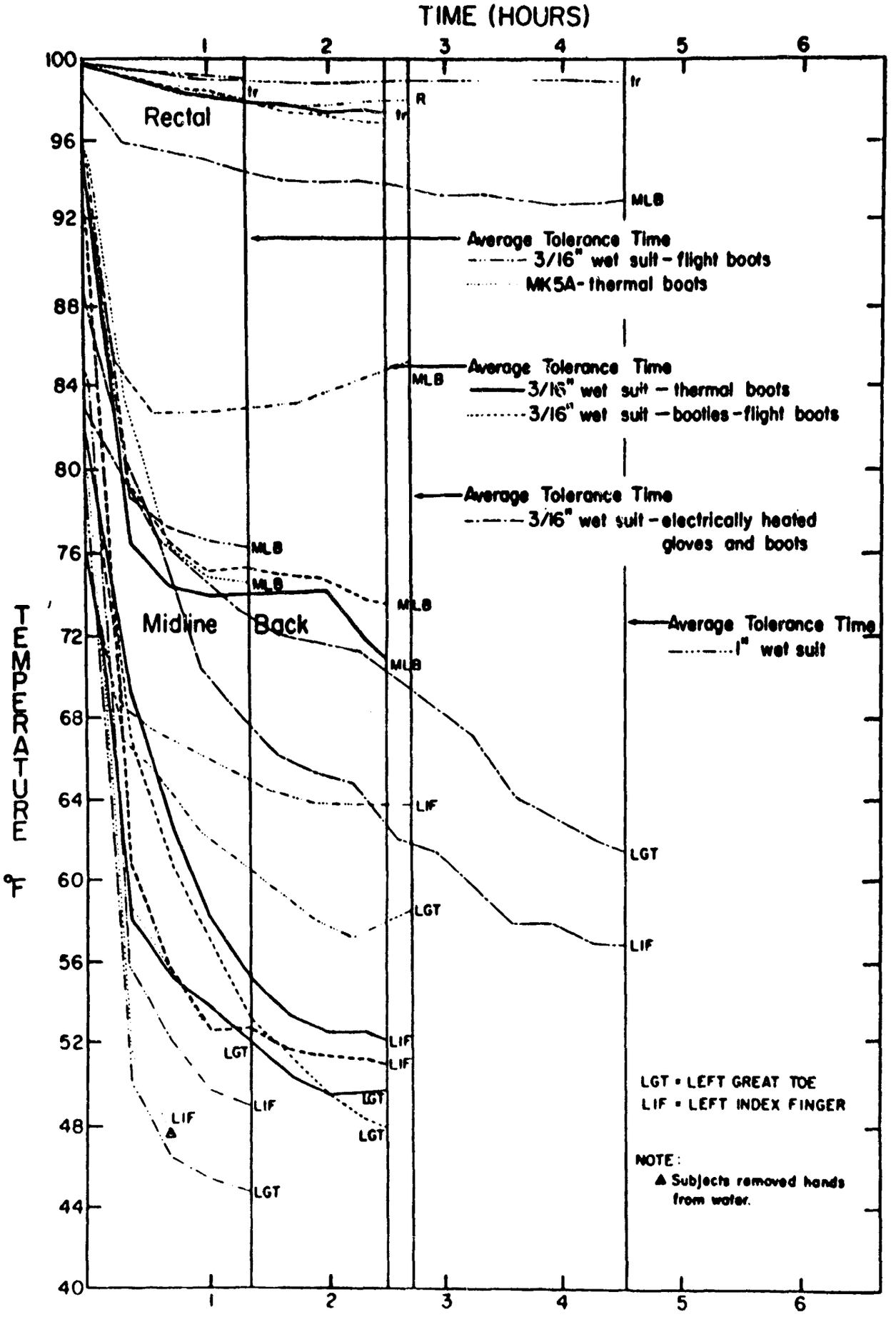

Fig. 2 Mean Temperatures During 40°F Water Immersions.

The mean finger temperature had decreased to 49°F by the end of the experiment while mean foot temperatures decreased to 50.2°F within 20 minutes, and had further decreased to 45°F when the immersion was terminated.

CONFIGURATION D at 40°F: (MK5A anti-exposure suit). Five experiments were conducted in this series ranging in duration from 1 hour to 1 hour and 40 minutes, with an average of 1 hour and 20 minutes. The mean rectal temperature decrease after 1 hour was 1.5°F. The back temperature decreased to 75° within one hour and the mean toe temperature reached 52°F within one hour. The mean finger temperature decreased to 47.6°F within 40 minutes and all subjects removed their hands from the water in order to prolong the experiment, (Fig.2). The mean total body heat loss was calculated to be 246.8 kcal/m^2/hr or 4.9 times the pre-immersion value for these five subjects.

CONFIGURATION E at 40°F: (3/16" wet suit, electrically heated gloves and boots).

The five experiments conducted with subjects wearing the 3/16" wet suit and electrically heated boots and gloves varied in duration from 2 to 3 hours, with a mean duration of 2 hours and 43 minutes. In this series of experiments heat was applied to the hands and feet in varying amounts after they had cooled to

approximately 60°F. A total of 60 watts power distributed 15 watts to each boot and glove was normally sufficient to maintain temperatures in these areas above the pain threshold (TABLE III); increases in wattage resulted in corresponding temperature increases. With this configuration it was possible to prevent the foot pain which had caused termination in 24 of 27 wet suit experiments in 40°F water. All five subjects in this series terminated the experiment at their request because of severe cramps in the stomach and/or groin. The mean rectal temperature decrease closely paralleled other experiments with subjects wearing wet suits in 40°F water.

CONFIGURATION F at 40°F: (1" wet suit - 4 ¼" UNF coveralls, booties, and mitts). Five experiments conducted with subjects wearing 4 ¼" unicellular foamed neoprene suits had a mean duration of 4.5 hrs (3.0-5.3). Mean temperature recordings at the end of 3 hrs were as follows: 1) rectal, 99°F; MLB, 93°F; 3) LIF, 61.7°F; 4) LGT, 68°F. All experiments in this series were terminated due to limited mobility of the subject (Fig.3) rather than temperature loss. It is noted that even with this amount of insulation (the theoretical ultimate protection against cold in air of 4 CLO* of insulation)

finger and toe temperatures decreased to 56°F and 58°F respectively by the time the experiment was terminated. The mean rate of total body heat loss was 71.42 kcal/m^2/hr, 1.3 times the pre-experiment measurement, (Table [illegible]).

CONFIGURATION G at 60°F: (NUDE). As a comparison, five experiments were conducted with nude subjects immersed in water at 60°F. The mean immersion time of these five was 1.8 hours (1.2-2.5) Four of the five subjects terminated the experiments because of severe cramps in the stomach and/or groin. Only one experiment was terminated due to loss of body heat when the subject's core temperature decreased to 95°F after 1.7 hours. All skin temperatures decreased to near water temperature within 10 minutes of water entry with shivering and discomfort experienced immediately upon immersion. Mean rectal temperature after 1 hr had decreased 2.0°F. Mean rate of total body heat loss was 252.9 kcal/m^2/hr, approximately 5 times that of the pre-immersion value of 50.0 kcal/m^2/hr while subject was sitting quietly beside the pool in room air (72°F), (Fig.4).

*CLO is an arbitrary unit of insulation and is the amount of insulation necessary to maintain comfort and a mean skin temperature of 33.3°C in a room at 21°C with an air movement not over 10 ft/min., humidity not over 50%, and body metabolism of 50 kcal/m^2/hr. On the assumption that 76% of the heat is lost through the clothing, a CLO may be defined as the amount of insulation that will allow the passage of 1 kcal/m^2/hr with a temperature gradient of 0.18°C between the two surfaces.

TABLE III. MEAN BODY HEAT LOSS IN 40°, 50°, AND 60°F WATER

WATER TEMP. °F	SUBJECTS (number)	DURATION (hrs)	CLOTHING ASSEMBLY	HEAT LOSS						
				EXTREMITY °F				T_R*** DECREASE	TOTAL BODY	
				LGT*		LIF**				
				PRE	POST	PRE	POST		CONTROL	HEAT LOSS
40°	5	4.5	1" wet suit	83.6	58.0	89.6	56.0	0.4	53.3	71.4
	10	2.5	3/16" wet suit thermal boots	77.2	49.7	81.7	52.1	2.1	52.7	171.6
	5	2.7	3/16" wet suit el. heated boots & gloves	74.0	58.4	80.7	63.8	1.5	55.2	128.1
	5	1.3	MK5A	74.1	50.0	79.5	51.6	1.8	50.2	246.8
50°	10	4.1	3/16" wet suit thermal boots	80.3	53.5	89.4	55.2	1.8	58.7	136.0
	5	0.98	NUDE	77.5	50.0	82.9	50.0	3.0	41.2	388.8
60°	4	6.0	3/16" wet suit thermal boots	76.8	62.3	90.1	61.5	1.8	53.8	95.5
	5	1.8	NUDE	76.9	60.1	71.3	60.0	2.5	50.0	252.9

*LGT = LEFT GREAT TOE
**LIF = LEFT INDEX FINGER
***T_R = RECTAL TEMPERATURE °F

Fig. 3 Subject Clothed in 1 inch Wet Suit. (4 ½" Unicellular Neoprene Foamed Coveralls, Boots, and Mitts)

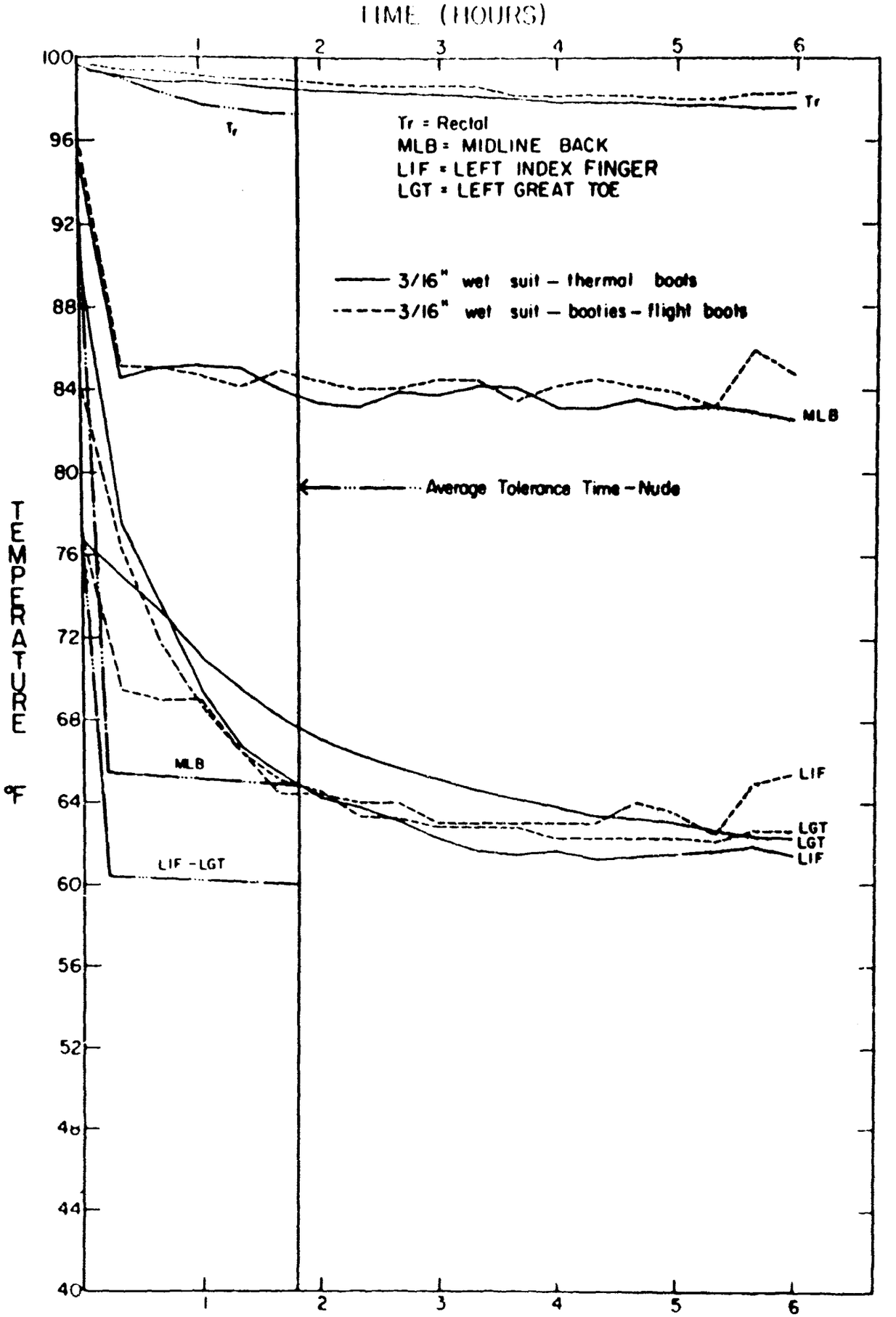

Fig. 4. Mean Temperatures during [illegible] Water Immersions

CONFIGURATION H at 50°F: (Nude). Five experiments were also conducted with nude subjects immersed in water at 50°F (Fig. 5). The mean immersion time of these five was 0.98 hours (0.6-1.5). Three of these subjects felt faint and were disoriented in less than an hour and had to be removed from the immersion pool. One of these subjects (asthenic-specific gravity 1.074) shivered very little. He was, therefore, not able to maintain his core temperature which fell 5.53°F within 38 minutes. He became faint and had to be removed from the pool. Four of the five subjects requested termination of their experiments. One of these subjects requested termination when be became disoriented and faint; his core temperature at his time had fallen 4°F. One pyknic subject (specific gravity 1.015) who had the least difficulty but who requestd termination remained 87 minutes with a loss of core temperature of 2.2°F and a total body heat loss during this time of 300 kcal/m^2/hr. With the exception of the asthenic subject, the other four shivered violently and suffered cramps almost from the time of entering the water with intense pain in the hands and feet. All skin temperatures decreased to near water temperature in less than 10 minutes after entering the water. The mean body heat loss was 388.8 kcal/m^2/hr.

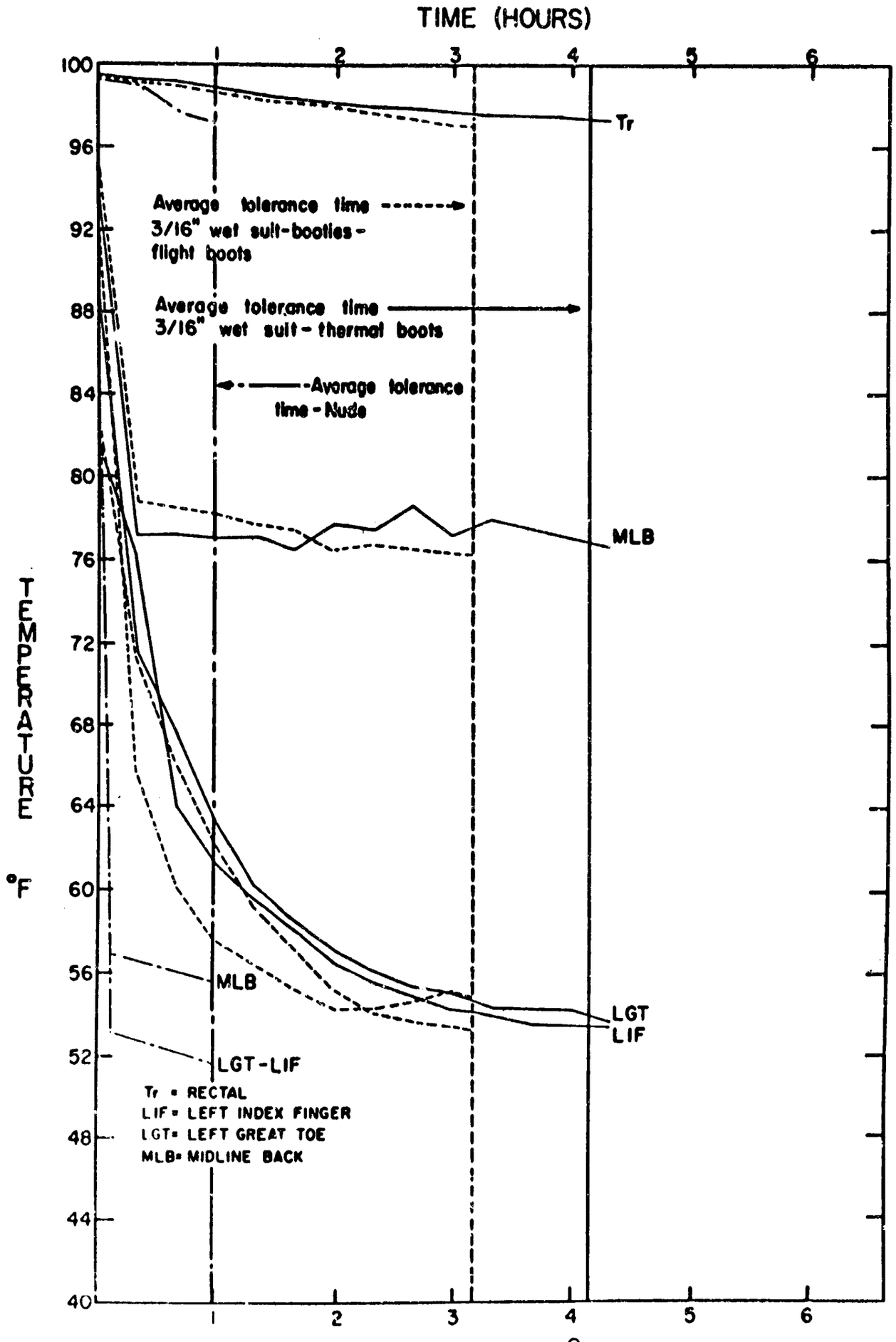

Fig. 5 Mean Temperatures During 50°F Water Immersions.

DISCUSSION:

Ordinarily, the unicellular foamed neoprene wet suit affords approximately fourteen pounds of buoyancy at water surface which is enough to keep a person floating with part of his body, feet, and hands out of the water. As has been demonstrated in this laboratory, such conditions decrease total body heat loss. In rough seas, however, a person is buffeted and splashed by the waves so that the advantages of such buoyancy from the standpoint of conserving heat is lost. These laboratory tests were designed to study subjects in various configurations of anti-exposure attire under the most severe conditions possible. Weighted belts were worn to overcome the natural buoyancy of the suit and to keep the subjects immersed to neck level with the hands and feet immersed at all times.

One of the criteria for the termination of the experiments was a decrease in extremity temperature to 45°F and five experiments were terminated due to this cause. Until numbness sets in, temperatures below 55°F are very painful. In water near freezing, extremity temperatures fall quickly so that such immersions are frequently less painful than those in 40°F and 50°F water. A willingness to accept pain over a long period of time is always a factor in voluntary tolerance time which in turn is dependent often upon the motivation of the subject. Most subjects requested termination of their

exposure because of muscle cramps and/or severe pain in the hands and feet.

Configuration A, the wet suit and thermal boots proved to be the best clothing assembly both from the standpoint of protection and of comfort. Two other variations of foot protection were tested as likely preferences of aviators and flight personnel. Configuration B, the wet suit, wet suit booties and flight boots, is an assembly which an aviator would probably favor since he would normally be wearing his leather flight boots and conceivably would only have to don the wet suit booties prior to flight. However, when wearing the booties he would have to wear flight boots two sizes larger than his usual size to be comfortable. In addition, the inability of the booty to mold to the foot accentuates the discomfort experienced when foot temperatures are below 55°F. In the 50°F immersions, the mean tolerance times of Configuration B, were shortened by almost an hour (TABLE I) due to the discomfort factor since the temperatures of the extremities in both Configurations A and B fell to the same levels. In 40°F water, tolerance times for Configurations A and B were approximately equal. However, Configuration A (thermal boots) was found to be more comfortable. Another configuration tested as one which helicopter crews might favor was that of wearing flight boots over woolen socks rather than thermal boots with the wet suit assembly.

Under such conditions, the mean tolerance time was only 80 minutes or approximately half the time of the subjects protected with either thermal boots or flight boots over wet suit booties.

In the experiments conducted to simulate a pilot's having to enter the water suddenly after being in a warm cockpit where he had been sitting with his wet suit jacket partially unzipped and not wearing gloves and hood, all were able to complete the zipping up of the jacket and donning of the hood and three-fingered gloves within three minutes of entering the water. The tolerance times of these subjects were not found to be shortened by such entry into cold water prior to donning hood and gloves.

The MK5A anti-exposure suit afforded approximately one half the protection of the wet suit with thermal boots. (TABLE I, Fig. 2) Seepage of water into the suit was a common event with water collecting in the boots. This fact, combined with the rapid loss of heat from the hands clothed in regulation leather gloves of this assembly, terminated these runs within 80 minutes. The CLO* value of the MK5A assembly in air is 2.05 but in the circulating water it is 0.57 or 0.2 less than the foamed neoprene wet suit under similar conditions (TABLE IV).[10] Thus, even when watertight, the MK5A would offer less protection against the cold of immersion. In addition, intense diuresis results in a very short time from the negative

TABLE IV: TOTAL INSULATING VALUES IN AIR AND WATER*
(clo units)

SUIT	AIR	STILL WATER	WATER FLOWING 1 gpm	RAPIDLY STIRRED WATER
Nude Copper Manikin	0.62	0.14	----	0.11
MK5A Anti-exposure suit	2.05	0.56	0.57	----
Underwater Swimmers Wet suit (¼" foamed Neoprene)	1.48	0.76	0.77	0.71
Underwater Swimmers Wet suit (3/16" foamed Neoprene)	1.32	----	0.78	----

*Tests conducted at the U. S. Army Research Institute of Environmental Medicine, Natick, Massachusettes, November, 1964.

pressure breathing of immersion as well from cold. The integrity of any dry suit would, therefore, be breached under these conditions in a very short time.

The tolerance times determined by these experiments give only a rough approximation of what the survival times might be. Certainly in all cases the survival times are longer than tolerance times for none of the experiments were terminated due to an immediate hazard to life. Rather, those conducted in water colder than 60°F were stopped because of severe muscle cramps and/or pain in the hands and feet. In an attempt to estimate possible survival times, comparisons were made of the rate of total body heat loss between subjects immersed in the multiple layered UNF garment, 1 inch thick, which in air would provide the theoretical ultimate of protection against cold (4 CLO of insulation TABLE IV). Control values for all experiments were taken just prior to the immersion period with the subjects sitting quietly in room air (72°F). When clothed in the four ¼ inch thick wet suits in 40°F water, the mean total body heat loss of 5 subjects was 71.42 kcal/m^2/hr as contrasted to 53.3 kcal/m^2/hr of the pre-immersion measurement. All body temperatures stabilized at normal values with the exception of the hands and feet which decreased to 56°F and 58°F respectively by the end of four and one half hours when the experiment was terminated due to discomfort caused by the rigidity of the 1" of neoprene foam all over the body.

Although no one would wear 1" of insulation, some form of supplying heat equal to 4 CLO of insulation will keep personnel comfortable in water as cold as 40°F for long periods of time. However, it also becomes apparent that even this amount of insulation on the hands and feet is not adequate without some additional means of supplying heat.[10] The five experiments with subjects wearing the 3/16" wet suit and electrically heated boots and gloves demonstrated that the temperature of the extremities could be maintained above the pain threshold even though the total tolerance time was not extended by any appreciable amount in 40°F water due to muscle cramps. The mean total body heat loss with this configuration of clothing was 128.1 kcal/m^2/hr (TABLE III) 2.3 times the mean pre-immersion control value.

The tolerance time of 5 nude subjects immersed in 50°F water was less than an hour (0.98). Four of the five subjects had to be assisted or taken from the pool. The fifth subject, an obese person, lasted 87 minutes, had a core temperature loss of 2.2°F and a total body heat loss of 300 kcal/m^2/hr or 7.46 times his pre-immersion measurement of 40.2 kcal/m^2/hr. Thus, at 50°F an obese person who shows little effect at higher water temperature as contrasted to other body types is unable to continue at 50°F much longer than average time. Three of the subjects complained of being faint or disoriented.

Shivering in most cases was violent, cramps were present almost from the time of entering the water and pain in the hands and feet was intense. One subject's rectal temperature decreased 5.53°F within 38 minutes. This subject did not shiver much, and, therefore, was not able to maintain his temperature. In contrast when wearing Configuration A (3/16" wet suit and thermal boots), ten subjects had a mean tolerance time of 4.1 hours (2.5-5.0) with a total body heat loss 2.3 times the normal. However, all subjects' hands and feet temperatures decreased below 55°F by the end of the experiment.

The mean tolerance time of nude subjects in 60°F water was 1.8 hours (1.2-2.5) with a mean total body heat loss of more than 5 times that of the mean control value and 2.6 times that of subjects dressed in 3/16" unicellular foamed wet suit and thermal boots. Four of the five nude experiments were terminated in less than 2.0 hours because of subjective complaints of muscle cramps, fatigue and generalized coldness. On the other hand, subjects wearing the 3/16" wet suit had no such complaints and after six hours of immersion these experiments were terminated because the core temperatures of subjects had stabilized. It becomes apparent that the most serious hazard relating to survival in moderately cold water is loss of body heat, understandable since water allows a rate of heat exchange approximately twenty-five times that of air at the same temperature. However,

with the protection of the 3/16" wet suit and thermal boots it has been demonstrated that tolerance times are approximately double the present accepted survival times.[13] Actual survival times, when wearing the UNF 3/16" wet suit would be even longer.

CONCLUSIONS:

1. Personnel clothed in the 3/16" UNF wet suit and thermal boots had the same tolerance time when immersed to neck level in circulating 40°F water as those clothed in 3/16" wet suit, wet suit booties, and flight boots- 2 hours and 30 minutes. However, those wearing the thermal boots were much more comfortable.
2. Personnel wearing 3/16" wet suit and flight boots alone had a mean tolerance time approximately half that of those wearing the thermal boots when immersed in 40°F water.
3. Personnel wearing the MK5A dry suit and thermal boots had approximately half the time of those wearing the 3/16" wet suit and thermal boots.
4. Mean tolerance time wearing the 3/16" wet suit and thermal boots in 40°, 50°, and 60°F water is not an indicator of survival time per se, as only 13% of the subjects had to terminate their immersion due to pre-determined criteria set down to insure the safety of the subject and to preclude any physical injury. It has been demonstrated that tolerance times are more than double the present suggested

times;[9] survival times are, therefore, in excess of these estimates. Table V outlines the previously suggested tolerance times in water for personnel wearing 3/16" wet suit, wet suit booties and N-1 field shoes as well as the mean tolerance times demonstrated in these experiments for personnel wearing the 3/16" UNF wet suit and thermal boots.

TABLE V. PROPOSED VERSUS DEMONSTRATED TOLERANCE TIMES (HOURS) IN WATER AT 40°, 50°, and 60°F.

Temperature	Tolerance Times (hrs)	
°F	Proposed	Demonstrated
40°	1.0	2.5
50°	2.0	4.1
60°	4.0	6.0*

*Immersion terminated because all temperatures had stabilized.

REFERENCES

1. Spealman, C. R. The relationship between foot temperature and amount of insulation surrounding the foot immersed in cold water. NMRI, NNMC, Bethesda, Md., Research Report No. 2, 11 Mar 1944.
2. Spealman, C. R. Early changes occurring in feet exposed to cold water and evaluation of insulation as a means of protection. NMRI, NNMC, Bethesda, Md., Research Project X-297, Report No. 3, 17 May 1944.
3. Behnke, A. R. and C. P. Yaglou. Responses of human subjects to immersion in ice water and to slow and fast rewarming. NMRI, NNMC, Bethesda, Md., Project X-189, Report No. 11, 23 Mar 1950.
4. Martorano, J. J. Evaluation of Diver's Dress Suits in Maintaining Body Temperature in Cold Water. Report NMFRL, Camp Le Jeune, N. C. XI: 19, Oct. 1961.
5. SantaMaria, L. J., Damato, J. J., and M. H. Radliff: A Physiological evaluation of the diver's wet suit in simulated flight and emergency environments. Aerospace Med. 35: 144-147, 1964.
6. Damato, J. and M. H. Radliff. Evaluation of the Divers' wet suit as considered for use by pilots of helicopter and fixed-wing aircraft. Aerospace Crew Equipment Laboratory, Naval Air Engineering Center, Philadelphia, Pa.

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13 ABSTRACT

The type of flights performed by helicopters require particular garments for their aircrews as follows: (1) Water entry by aircrew is by way of water collision so that there is a high probability of damage to the survival garment; (2) The short flight radius of the helicopter ensures that the time-distance from a potential rescuer should be relatively short, so that rescue should be expected in less than 4 hours; (3) The suit must be wearable without an air ventilated suit for cooling and still be usable in high cockpit temperatures up to 90° F; and, (4) The low altitude of flight allows no time to don or zipper up a survival garment so that there should be no significant penalty for entering the water with the garment partially unzipped.

Laboratory experiments using a variety of anti-exposure assemblies demonstrated that the 3/16" foamed neoprene wet suit, mittens, hood, and insulated rubber "thermal" boots provided the most comfortable and efficient configuration. Tolerance times were established for such clothing in 40°, 50°, and 60°F. water.

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	ROLE	WT	ROLE	WT	ROLE	WT
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